Elastic and Inelastic Scattering of 84 MeV 14N Ion on Light Nuclei

著者	Yamaya T., Shinozuka T., Kotajima K., Fujioka M., Morita S., Sato O., Hirota J. I., Ohi T., Sato K., Washio T.
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I. 2 Elastic and Inelastic Scattering of 84 MeV ^{14}N Ion on Light Nuclei

Yamaya T., Shinozuka T.*, Kotajima K.**, Fujioka M.*, Morita S., Sato O., Hirota J.I., Ohi T.**, Sato K.** and Washio T.**
Department of Physics, Faculty of Science, Tohoku University
Cyclotron and Radioisotope Center, Tohoku University*
Department of Nuclear Engineering, Faculty of Engineering, Tohoku University**

In recent years, the elastic scattering of various light heavy ion projectile from various targets have been studied in a systematic studies. An aim of these studies is to gain an understanding of a heavy ion interaction process. From the analysis of $^{16}O+^{28}Si$ elastic scattering data for eleven energies from 33 to 214 MeV[1], the data demanded a shallow potential whose real part had a depth of about 10 MeV and whose imaginary part was deeper but had a somewhat smaller radius and surface diffuseness. On the other hand, potentials of Woods-Saxon squared form, as well as double-fold potentials using realistic nucleon-nucleon interactions, were used in the analysis of the data by Satchler et al.[2] and equally good fits were also obtained. In the present work, the elastic and inelastic scattering of ^{14}N ions from ^{9}Be, ^{12}C, and ^{28}Si have been studied in order to examine deep and shallow potentials in the phenomenological optical model potential. Furthermore, the examination of a projectile dependence of the heavy ion interaction process absorbs much interest. In particular, a comparison of ^{6}Li and ^{9}Be projectiles with other light heavy ions such as ^{12}C, ^{14}N, and ^{16}O suggest that the weak binding of ^{6}Li and ^{9}Be may be responsible for the break-up effect. Also, an evidence for nuclear rainbow scattering, as is found for light ion projectiles, has been expected for light heavy ions. In the present experiment, we measured cross sections of elastically and inelastically scattered ^{14}N ions from ^{9}Be, ^{12}C, and ^{28}Si. Beam of $^{14}N^{5+}$ at 84 MeV was provided by the CYRIC AVF cyclotron. Current of a few charge nA of $^{14}N^{5+}$ was obtained at a beam stopper. Since structures in the angular distributions from light targets are strongly oscillatory, the beam spot at the target was collimated in the size of about 1×4 mm with a beam collimator system to get good angular resolutions, and an angular resolution $\Delta\theta = 0.4°$ was estimated for the detector slit aperture. Details of the experimental procedure have been reported in a CYRIC Annual Report in 1982.[3]

The elastic data were analyzed in order to examine the deep and the shallow optical model potentials. Automatic parameter searches made using the code ELAST2.[4] Elastic scattering angular distributions were compare to the DWBA calculation curves in fig. 1. The solid and the broken curves are results of DWBA calculations using the shallow and the deep potentials, respectively, by Cramer et al.[1] The quality of fits are comparable for both potentials but are not yet complete fits to the data. Parameters of the optical model potential are listed in table 1. Some of the optical model parameters were varied to obtain better fit to the angular distributions of the elastic data. Parameters obtained from the analysis in the $^{16}O+^{28}Si$ system[1)] reproduced the DWBA calculation curve in the $^{14}N+^{28}Si$ system. But this calculation curve did not well fitted to the present data. That is, the angular distribution of ^{14}N scattered elastically from ^{28}Si shows more diffractive structure than the angular distribution of ^{16}O. Then, a spin-orbit coupling part in the shallow potential played a significant role for a fit to the data. In the system $^{12}C+^{14}N$, the experimental angular distribution show the nuclear rainbow scattering diffraction, however, such a diffraction should be observed at higher energies. In the system $^{9}Be+^{14}N$, the incident energy of ^{9}Be as projectile correspond to 54 MeV. Then ^{9}Be shares a number of properties in common with ^{6}Li, namely, both have ground state which are quite weakly bound compared with other projectile studied.

We have been analyzed for the inelastic scattering to the first 2^+ states of ^{28}Si and ^{12}C, and the $5/2^-$ state of ^{9}Be using the DWBA calculations. The standard first-order deformed optical potential was used in conjunction with the Woods-Saxon potential of table 1, for all three targets. Coulomb excitation was also included in the usual way. The code DWUCK was used. Angular distributions are compared with the results of DWBA calculations in fig. 2. Magnitudes of the deformation parameter β_2, determined from the normalization of the theoretical curves to the data, are listed in comparison with deformation parameters obtained from other experiments in table 2. For the ^{12}C target, the value of β_2 extracted from the present data was in general agreement with the result of a proton inelastic data, however, the β_2 values of ^{9}Be and ^{28}Si targets were disagreement with other results.

References

1) Cramer J. G. et al., Phys. Rev. C 14 (1976) 2158.
2) Satchler G. R., Nucl. Phys. A279 (1977) 493.
3) Yamaya T. et al., CYRIC Annual Report 1982, p. 9.
4) Igarashi M., Automatic Search for Optical Potential Parameters, private communication, 1970.

Table 1. Optical model parameters for the DWBA calculations.

$^{14}N+^{28}Si$ E_N=84 MeV

	V_0 (MeV)	r_R (fm)	a_R (fm)	W_0 (MeV)	r_I (fm)	a_I (fm)	V_{so} (MeV)	r_{so} (fm)	a_{so} (fm)	r_c (fm)
shallow	10.18	2.42	0.618	39.0	1.97	0.552	0.842	1.97	0.618	1.79
deep	100.0	1.67	0.797	165.0	1.59	0.764	—	—	—	1.79

$^{14}N+^{12}C$ E_N=84 MeV

	V_0 (MeV)	r_R (fm)	a_R (fm)	W_0 (MeV)	r_I (fm)	a_I (fm)	V_{so} (MeV)	r_{so} (fm)	a_{so} (fm)	r_c (fm)
shallow	9.45	3.22	0.604	26.55	2.55	0.552	0.803	2.77	0.618	2.053
deep	100.0	2.15	0.7	10.0	2.65	0.32	—	—	—	2.053

$^{14}N+^{9}Be$ E_N=84 MeV

	V_0 (MeV)	r_R (fm)	a_R (fm)	W_0 (MeV)	r_I (fm)	a_I (fm)	V_{so} (MeV)	r_{so} (fm)	a_{so} (fm)	r_c (fm)
shallow	11.75	2.68	0.608	23.4	2.66	0.552	0.45	2.68	0.640	2.16
deep	100.0	1.6	0.77	20.0	2.60	0.60	—	—	—	2.16

($R_r=r_R A_T^{1/3}$, $R_I=r_I A_T^{1/3}$, $R_{so}A_T^{1/3}$, $R_c=r_c A_T^{1/3}$)

Table 2. Deformation parameters extracted from the present data in comparison with the results from other reactions.

		E_{Lab} (MeV)	2
^{28}Si	^{12}C	19 48	0.4
	P	49	0.37
	^{14}N	84	0.16
^{12}C	^{9}Be	39.68, 43.75	0.267
	P	46	0.63
	^{14}N	84	0.50
^{9}Be	P	46	1.4
	^{14}N	84	0.42

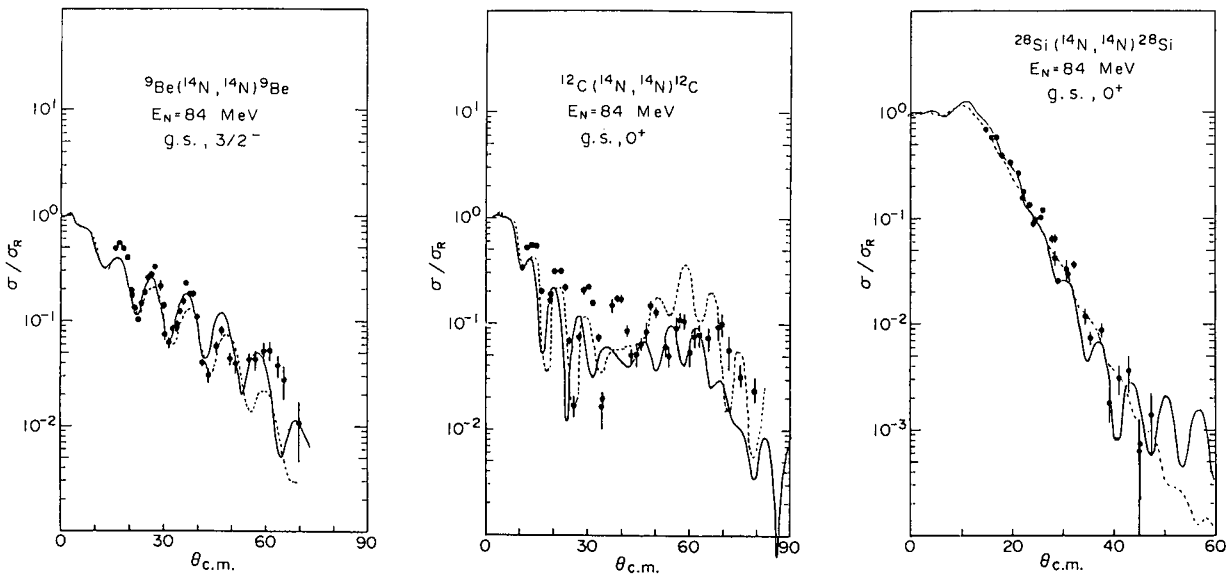

Fig. 1. Elastic scattering of 84 MeV ^{14}N from ^{9}Be, ^{12}C, and ^{28}Si. The solid curves are the results of the DWBA calculations using the shallow potential including a spin-orbit coupling force. The broken curves are from the calculation using the deep potential.

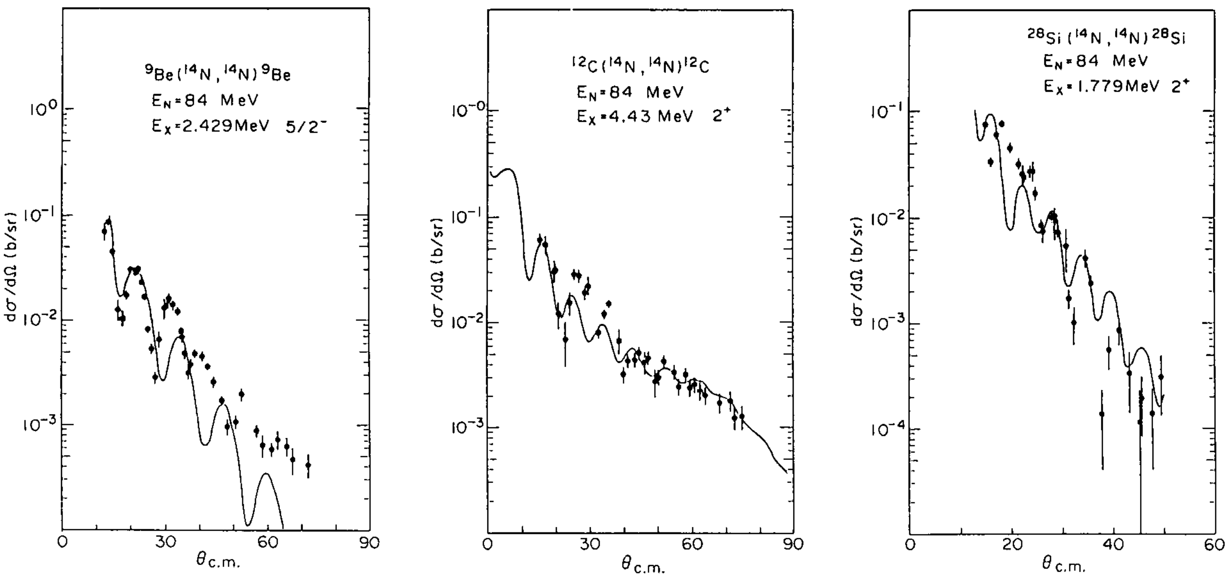

Fig. 2. Inelastic scattering of 84 MeV ^{14}N exciting the 2^+ states at 1.78 MeV in ^{28}Si and at 4.43 MeV in ^{12}C, the $5/2^-$ state at 2.43 MeV in ^{9}Be. The curves are the results of the DWBA calculations using the optical model potential fitting to the elastic data.